

SOME OCCURRENCES OF PESTICIDES IN THE MARINE ENVIRONMENT

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Introduction

The presence of organochlorine pesticides in rainwater was first reported by Wheatley and Hardman in 1965. They found a few parts per billion of lindane, dieldrin and DDT in rainwater collected in central England. In 1966 Cohen and Pinkerton noted the rain-out of organochlorine pesticides at several points in the United States. They also reported the translocation of pesticides by dust. Bamesberger and Adams (1966) have done a survey for aerosol and gaseous phase of those compounds. Recently Risebrough, Griffin and Goldberg (1968) have reported these pesticides in Atlantic tropical trade winds at the island of Barbados, West Indies.

The purpose of this work was to explore the occurrence of organochlorine pesticides in several sectors of the marine environment. Firstly, it was to confirm the presence, qualitatively and quantitatively, of pesticides at Barbados. Several pesticides not previously noted were found, indicating that the given input value to the Atlantic is at least twice as great as reported. Secondly, it was to determine if organochlorine pesticides occurred in tropical rain showers and cyclones and if so, if they could be recovered and measured by the emulsion extraction method recently developed by the author. In the reports mentioned above, large amounts of sample (liters), long sampling times (days) and elaborate recovery, clean-up and separation procedures were required in order for the minute amounts of pesticides present to be detected. Because the emulsion extraction method allows 10^4 direct concentration, these problems are eliminated. This method has revealed the presence of organochlorine pesticides in tropical trade wind showers and cyclones with much higher concentrations in severe cyclones. Thirdly, it was to determine if there is a relationship between the pesticide dust input and pesticide occurrence in tropical trade wind showers and cyclones. It seems probable that air-sea interaction is the controlling mechanism with sea slicks acting as surface concentrators of pesticides.

Procedures

Obtaining Samples:

Details of how dust is collected at Barbados with extreme care to avoid contamination have been given (Delany *et al.*, 1967; Prospero, 1968). Of importance here is the fact that when the dust is washed by water from the collector nets, it is allowed to settle in this water in a bucket. Three stages of settling are used in successively smaller containers with the wash water being siphoned off and discarded. Local deionized water is used. For this report, water was distilled and hexane extracted in Miami so that it was free from chlorinated pesticides to less than 0.01 parts per trillion. Thirty liters of water was sent by air to Barbados in 12-lgal. glass bottles with teflon lined caps. This provided samples of wash water for 12 consecutive days. Wash water was siphoned back into the 1gal. glass bottle from which it came, sealed and returned by air to Miami. Samples were taken from November 23 to December 4, 1968. Dust samples collected during 1967 were used for comparison since the dust was collected during the above time will not be available for some time due to the accidental demise of the operator of the Barbados dust station in early December.

It had been intended to collect airborne samples of hurricane rain in specially prepared sampling bottles, particularly in hurricanes that continued from far at sea across land masses. However, promised cooperation by ESSA was withdrawn at the last minute on each occasion of a hurricane within sampling range and no airborne samples of 1968 hurricanes were obtained.

Airborne hurricane water samples for the last three years collected for tritium analysis (Ostlund, 1967) were surveyed. These samples are collected in cleaned glass bottles with polyseal caps. Since the amount of water needed was considerably more than that usually collected, most samples were eliminated from consideration. However, two hurricanes were found, Fern on October 10, 1967 and Chloe on September 9, 1967, which provided large rain samples during their penetration. Fern was located in the Central Gulf of Mexico and Chloe was about 400 miles east of Bermuda.

Rain from 1968 trade wind showers and tropical cyclones was collected at the Institute of Marine Sciences located on Virginia Key near Miami, Florida. Samples were collected on the roof of the tallest structure, about 15 m above ground. Rain was collected in a stainless steel tray and passed through glass tubing to a glass bottle. Tray, tubing and bottle were cleaned with acetone and hexane before each sample collection. Hurricane Abby and a tropical depression both occurred in June, 1968. Trade wind showers were collected during times of steady east and southeast wind from June to November, 1968.

Surface slicks were collected from Biscayne Bay and the Florida Current during June-August, 1968. Samples were collected in cleaned 200-mL glass bottles with teflon lined caps. A sample was taken by holding the lip of the bottle just under the surface of the water and allowing the slick to pull itself into the bottle, non-slick sea water samples were taken in the same manner. Duplicate samples for head gas analysis of organic compounds were taken in prepared bottles (Seba, 1968 Cotwin, 1969) at the same time as slick and non-slick sea water samples.

Analysis of Samples

Barbados wash water was partitioned against the same 100 mL of hexane in successive 100 mL aliquots. The original sample bottle was washed with the same 100 mL of hexane. The hexane was evaporated to 1/100 volume under a stream of high purity N_2 passed through molecular sieve. The hexane used, obtained from Burdick & Jackson Laboratories, Muskegon, Michigan, can be concentrated 10^3 with no interfering substances produced.

Barbados dust was analyzed by transferring a weighed aliquot to a clean glass vial with a teflon lined cap. Hexane was then added and the sealed vial placed in an ultrasonic cleaner. Ultrasonics very effectively pulverizes the dust making direct extraction possible. Hexane was evaporated to 1/10 volume.

The emulsion concentration method was used on all rain water samples. In this method, hexane is introduced to the water sample in a ratio of 1:100 and then vigorously stirred with a teflon coated magnetic stirring bar to form an emulsion. While this emulsion will not break, it will rise to the top upon standing. Ninety percent of the water can then be removed, leaving a hexane to water ratio of 1:10 which will break upon stirring. Extraction was done in the original sampling bottle. The hexane was then evaporated to 1/10 volume.

Sea slicks were directly extracted at 1:10 with hexane in the collection bottle. The hexane was evaporated to 1/10 volume.

Analysis of all hexane extracts was done on one of two similar instruments. A Beckman GC-5 gas-liquid chromatograph with a helium arc emission electron capture detector installed in December, 1968, or a specially designed Aereograph A-600B gas-liquid chromatograph with a Ni^{63} electron capture detector (Seba, 1968). Identification was done by both retention time correlation with FDA certified pesticide standards and the extractive paravalues method of Bowman and Beroza (1965). Three different columns were used so that different retention times could be obtained for any particular pesticide. The columns used were 5% QF-1 with 80/90 mesh Gas Chrom Q support, 3% SE-30 with 42/60 mesh Chromosorb G support and 3% AN600 with 80/90 mesh Anakrom Q support.

Very careful attention was given to every phase of the analysis to avoid any contamination or alteration of samples. Blanks and controls were run throughout and no contamination was found. Experience has shown that contamination usually

reveal its occurrence by an enormous amount of a particular compound in relation to others present. Six identical samples run on Hurricane Abby showed reasonable agreement.

Sea water samples were assayed for acetone, butyraldehyde and 2-butanone by the head gas method (Seba, 1968; Corwln, 1969). Analysis of the head vapors was done on a Beckman GC-5 gas-liquid chromatograph with dual hydrogen flame ionization detectors. Matched-columns of 10% Carbowax 20M with 60/80 mesh Chromosorb W support were used.

Results

Figure [TABLE] One shows the absolute amount of pesticides in each wash water sample and its concentration in the air at Barbados. Also noted tentatively on the basis of retention time but not confirmed due to unknown interfering peaks on the chromatograms were lindane, heptachlor epoxide and chlordane. The compounds producing the interfering pairs varied in intensity and number but some were present in all water and dust samples. The average value of pesticide in air obtained from the wash water was $86 \times 10^{-15} \text{ g/m}^3$. The values given in Figure One are based on a collection efficiency of 50% for particles greater than 1 micron (Delany *et al.*, 1967). Since the collection efficiency drops off rapidly for particles smaller than 1 micron, it should be emphasized that the values reported are only minimal and could be greater.

The 1967 Barbados dust gave a pesticide distribution very similar to that reported by Risebrough *et al.* (1968) for 1965-66. They gave an average value of $78 \times 10^{-15} \text{ g/m}^3$ of air whereas $82 \times 10^{-15} \text{ g/m}^3$ was found for the 1967 dust samples.

Of particular interest is the fact that slightly more pesticides were found in the wash water than in the dust and that p,p'-DDE was the major constituent with p,p'-DDT second in the wash water while the situation was reverse in the dust. It is felt that these values represent absolute background contamination since they are independent of dust load and so do not display seasonal variation as does the dust (Prospero, 1968).

Figure [TABLE] Two shows averaged values of pesticides for different types of tropical weather systems. A total of 23 samples were analyzed. Besides revealing the presence of a number of organochlorine pesticides, Figure Two shows a strong consistency between the tropical depression and Hurricane Abby. This would indicate not only the precision of the sampling method but that both cyclones had the same air mass structure. Of particular interest

Table 1. Amounts of pesticides in wash water samples and its concentration in air at Barbados.

Date (1968)	Air Volume $\times 10^6 \text{ m}^3$	Pesticide amounts in nanograms ($\times 10^{-9} \text{ g}$)					Amount in air $\times 10^{-15} \text{ g/m}^3$
		p,p'-DDT	p,p'-DDE	Dieldrin	o,p'-DDT	Total	
Nov. 23	1.2	2.8	23.6	0.6	0.1	27.1	45.2
Nov. 24	0.8	2.6	53.7	1.2		57.5	143.6
Nov. 25	0.7	5.9	64.2	1.3	0.1	71.5	204.2
Nov. 26	0.8	0.8	27.2	0.6	0.2	28.8	72.0
Nov. 27	1.0	0.2	37.9	0.9		39.0	78.0
Nov. 28	1.5	3.5	22.8	1.0	0.1	27.4	36.6
Nov. 29	1.5	5.8	23.1	0.4		29.3	39.0
Nov. 30	1.5	4.8	32.8	0.4		38.0	50.8
Dec. 1	1.3	4.2	57.7	0.5	0.2	62.6	114.0
Dec. 2	1.1	5.2	44.4	1.4	0.1	51.1	93.0
Dec. 3	1.5	2.2	72.0	1.0	1.4	76.6	102.4
Dec. 4	1.6	3.0	41.6	0.3	0.5	45.4	56.8

Table 2. Averaged values of pesticides for different types of tropical weather systems.

Weather system	Concentration in picograms ($\times 10^{-12} \text{ g}$)/L rainwater				
	Lindane	Chlordane	Heptachlor epoxide	p,p'-DDE	o,p'-DDT p,p'-DDT
Trade wind showers	1.0	1.6	2.0	0.1	2.4
Tropical depression	2.0		2.0		4.3
Hurricane Abby	2.0		2.0		4.3
Hurricane Fern	95	29	70	50	
Hurricane Chloe	185	73	225	143	

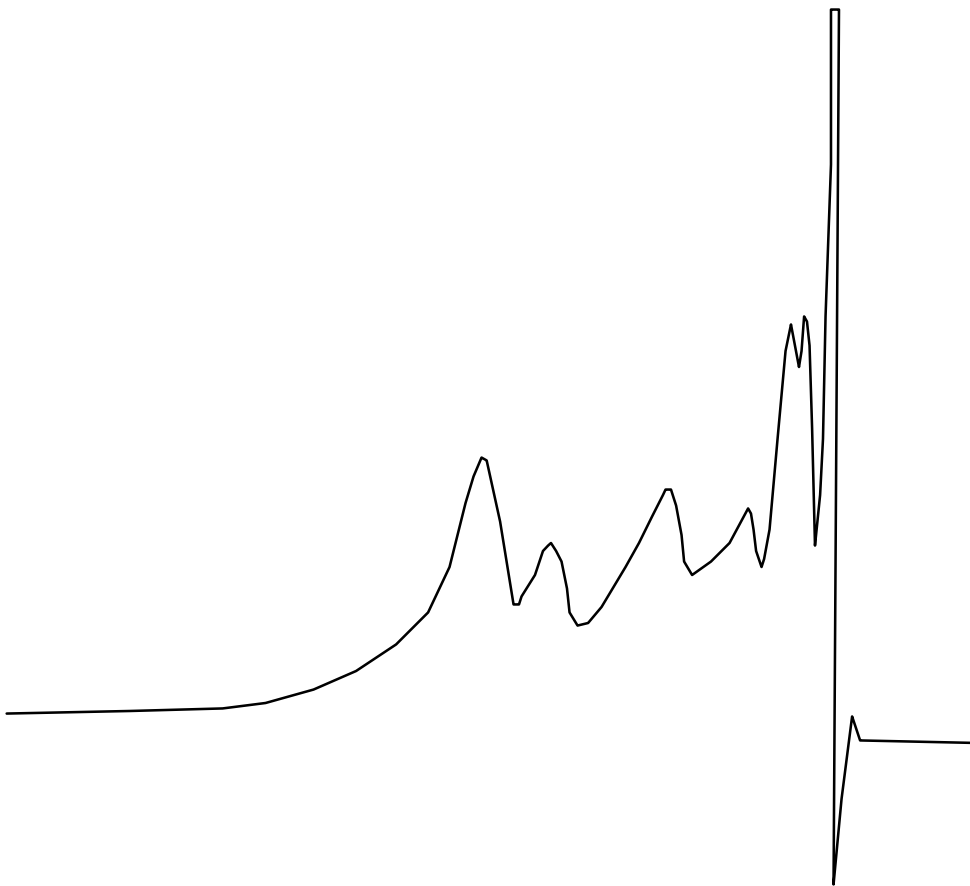


Figure 3. Chromatogram of pesticides in tropical rainwater. Separated on 5% QF-1 with 80/90 mesh Gas Chrom Q support. Column length, 1/8" o.d. x 6'; temperature 200 °C. Ni63 electron capture detector at 225 °C. Flow rate: 55 mL/min N₂.

is the greatly increased pesticide load in hurricanes Fern and Chloe. The highest concentration of pesticide was found in the cloud wall of Chloe, being almost twice that found on the fringe of the cyclone. A typical chromatogram is shown in Figure Three.

Figure [TABLE] Four gives the concentrations of pesticides in the sampled surface slicks. Also noted tentatively on the basis of retention time but not confirmed due to unknown interfering pairs on the chromatograms were lindane, heptachlor epoxide and chlordane. The values given are the average of several slick samples taken at the same location over a period of several weeks during June August, 1968. Five to nine samples were averaged. Some locations were sampled more often only because of the traceability during inclement weather. Variation was about 25% and sometimes occurred in duplicate samples of the same slick. A total of 53 samples were taken.

Figure Five shows the approximate location of the slicks and their relationship to the South Florida Flood Control Canal and the Florida Current. The canals were almost continuously flowing into Biscayne Bay during the sampling period due to extremely heavy rainfall. Drainage of the extensive agricultural area southwest of Miami is accomplished exclusively by these canals, particularly C-1 and C-100. Extensive aerial and boat surveys revealed that many of these slicks were semipermanent features. One slick near the Institute of Marine Sciences, associated with the

Table 4. Concentration of pesticides in surface slicks.

Slick number	Concentration of pesticides in parts per billion					Total
	p,p'-DDT	p,p'-DDE	Dieldrin	o,p'-DDT	Aldrin	
S-1	0.049	0.124	0.003	0.012	0.018	0.206
S-2	0.090	0.266	0.004	0.013	0.015	0.388
S-3	3.460	9.250	0.022	0.005	0.017	12.750
S-4	1.460	2.880	0.035	0.081	0.025	4.480
S-5	0.114	0.266	0.010	0.002	0.034	0.426
S-6	0.140	0.178	0.021	0.014	0.005	0.358
S-7	0.017	0.061	0.002	0.002	0.011	0.093

outfall of the Miami River, was noted everyday from June to December, 1968. Its width would vary greatly from a few meters to over 100 depending on the tide, wind and water outfall but its length and location were quite permanent. This permanence of slicks associated with water outfall has been reported for other locations (Ewing, 1950). Aerial photos revealed that during the period of June-August, 1968, about 10% of Biscayne Bay was covered with surface slicks with the coverage rising to 20% in the area around Turkey Point. The increase in slick area around Turkey Point is probably due to the increased Langmuir circulation caused by the instability in the water induced by the large thermal addition from the effluent of a power plant located at Turkey Point.

Of particular interest is the large number of pesticides noted and their distribution. Slicks off canals draining heavily farmed areas contained up to 137 times as much pesticide as surface slicks in the Florida Current. The Current can be taken as a background value for Caribbean waters as local shore water does not reach the main axis of the Florida Current as it flows past Miami.

Biological activity was very intense in the water immediately under the slicks in comparison to that in surrounding slick-free water. Large, dense schools of small fish (*Clupidae* and *Engraulidae*) occurred just under and in the slick. The location of slicks could often be determined before they could be observed by noting the feeding of sea gulls on these fish. Larger game and food fish were often observed feeding on the schools of small fish. Observations and conversations with local fishermen revealed that fishing usually was better when a slick passed under a bridge or pier. High biological activity from plankton to fish and dolphins in slicks has been carefully documented (Babkov, 1965). Numerous other authors have noted aspects of this activity (Bainbridge, 1953; Bary, 1953; and William, 1967).

Samples of water taken at the same time as the surface slicks generally had no detectable amounts of pesticides (less than 1 part per trillion). A total of 51 samples were analyzed. Sea water taken from Bear Cut inlet and distributed through a flowing salt water supply system at the Institute of Marine Sciences did not reveal the presence of any chlorinated pesticides during 1966 and 1967 when it was sampled on a weekly basis. The U. S. Geological Survey reports no detectable amounts of pesticide in C-2 and C-100 (Kolipinski and Higer, 1969).

The concentration of organochlorine pesticides was found to be selective. Three organic compounds, acetone, butyraldehyde and 2-butanone, have been recently reported as occurring in the Florida Current and other oceanic waters (Corwin, 1969).

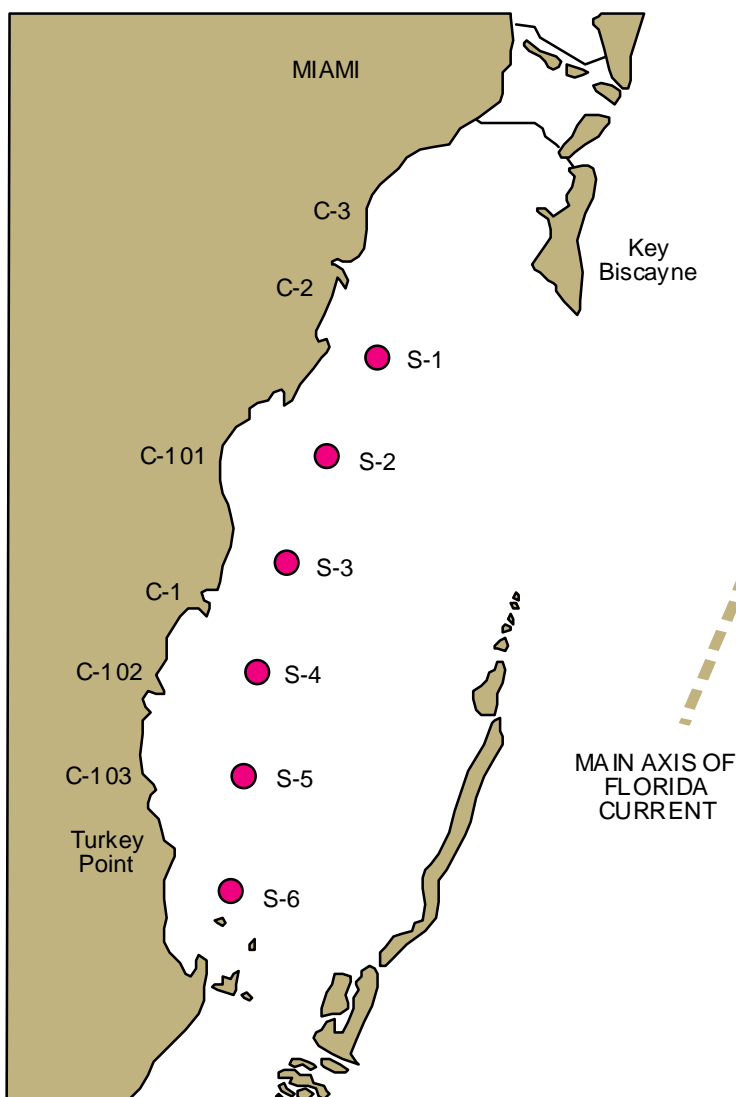


Figure 5. Location of slicks and their relationship to South Florida Flood control canals and the Florida Current. [ONLY APPROXIMATE CANAL LOCATIONS IN THE MAINLAND ARE NOTED.]

Table 6. Averaged concentration of organics in sea water and slicks.

Water sample type	Concentration of organics in mg/L		
	Acetone	Butyraldehyde	2-Butanone
Slick	0.0897	0.0267	0.0297
Non-slick	0.0396	0.0259	0.0297

compounds revealed their presence in all slick and non slick sea water sample taken. The averaged values are given in Figure [TABLE] Six. While there was some overall concentration of acetone and butyraldehyde in sea slicks, it was sporadic, independent of location and was never more than three fold, as compared to the at least 105 concentration of pesticides in some of the same slicks. The slight concentration of these three organic compounds may be due to their volatility and solubility.

Discussion

It had originally been thought the pesticide loading reported for Barbados air, 78×10^{-15} g/m³ (Risebrough, et al., 1968), might be too low because of the dissolution of pesticides into the wash water while the settling was taking place. The fact that more pesticide was found in the wash water than in the settled dust provides strong support for the conclusion reached by Risebrough et al. that the atmosphere is responsible for transporting significant quantities of pesticides to the open-ocean ecosystem. However, the distribution of pesticides in the wash water is somewhat different from that of the dust. This indicates a possibly different source than direct wind conveyance from the continents for these pesticides in marine air. Such an alternate source might be the sea surface, provided that mechanisms exist to concentrate and remove pesticides from it. For this reason, it is particularly interesting to note the collection of pesticides in sea water slicks.

Pesticides apparently exist in very low concentration in the open oceans. Although no surveys have been made of the occurs, their lack of detection in sea water in heavily polluted estuaries attests to this. Other investigators have found or set very low limits on pesticide concentration in estuaries (Kolipinski and Higer, 1969). In an east coast estuary so polluted with DDT that natural populations were probably being limited, DDT concentration was estimated at less than 50 parts per trillion (Woodwell, Wurster, Jr. and Isaacson, 1967).

Croker and Wilson (1965) deliberately applied DDT to a tidal marsh ditch at a concentration of 70 parts per billion. In less than 24 hour DDT could only be found in the surface water and these traces disappeared within 5 days. However, a patch of oil found 8 days after the application contained 133 parts per billion DDT.

Similarly, pesticides collected in surface slicks in Biscayne Bay and the Florida Current. Although their concentrations were not determinable in water, a concentration gradient must have existed because the slicks with the highest pesticide load occurred closest to the major outfalls. The rapid drop-off of pesticide load in the slicks away from the outfalls adds additional support to the argument that the value for slicks in the Florida Current is representative of Caribbean waters. Thus it is apparent that pesticides tend to collect at the water surface, particularly in surface films.

Up to a five fold concentration of dissolved organic carbon and up to a 1500 fold concentration for particulate carbon has been reported for sea water (Williams, 1967). The finding that acetone, butyraldehyde and 2-butanone, common to all samples, were barely concentrated, but in different proportions, while the pesticides were concentrated several orders of magnitude, demonstrates that the slick enrichment reported by Williams is not just a simple concentration process but a highly selective fractionation as well and so may be of considerable ecological importance.

The distribution of pesticides in the slicks was similar enough, particularly the high concentration of p,p'-DDE, to indicate perhaps some degree of causal relationship to the pesticides recovered from the Barbados wash water. The higher amount of p,p'-DDT in slicks may be a result of the continental pesticide dust impinging on the surface of the water. Such dust particles would tend to collect in surface slicks (Fox, Isacas and Corcoran, 1952).

The concentration of pesticides in surface slicks and the high degree of biological activity associated with them may explain several problems of concern to ecologists.

Sutcliffe, Jr., Baylor and Menzel (1963) found that when the rate of downwelling of the converging water masses exceeded the spreading speed of the slick, the film is probably compressed, collapsed and peptized into colloidal micells which are carried downward in the water column. These nutrient rich particles could be adsorbed and utilized by phytoplankton or could coalesce with other particles and become available to filter feeders, thereby increasing biological activity

under slicks. Babkov (1965) has found a large increase in phytoplankton productivity in slicks, yet Wurster, Jr., (1968) found that just a few parts per billion of DDT inhibited photosynthesis in marine plankton.

Wide variations in the amounts of pesticide residues are often found among individual fish, even those from the same estuary (Butler, 1966). It seems entirely possible that a fish associated with a slick off the C-100 canal would have less than 1/10 the pesticide uptake of a fish associated with a slick Just three miles to the south.

Sea gulls and pelicans were observed to dive through the slicks with their beaks open, thus undoubtedly taking up some concentrated pesticide. This probably helps to explain, in addition to biological magnification within their food chain, why carnivorous sea birds have been found to have the highest pesticide residue concentrations of all the estuarine fauna (Woodwell, Wurster, Jr. and Isaacson, 1967). Pesticide concentration in sea slicks may also explain the high amount of pesticide residues in wholly pelagic sea birds (Wurster, Jr. and Wingate, 1968). Furthermore, this mechanism may also explain the occurrence of pesticide residues in the fauna of Antarctic, extremely remote from many source of contamination (Sladen, Menzie and Reichel, 1966). Thus, the finding of much higher concentrations of DDT and its conjugates in slicks may also be of considerable ecological importance.

In the introductory papers mentioned, dust was generally felt to be the source of pesticides in the rainwater collected. If this is assumed to be true, the average value of organochlorine pesticides found at Barbados of $168 \times 10^5 \text{ g/m}^3$ can be used. The average m^3 of tropical trade wind contains about 25 mL of water (Sterns, 1969). This means that if all the pesticide dust were washed out during precipitation, an average liter of rain would contain $6.5 \times 10^{12} \text{ g}$ of chlorinated pesticides. This value is in agreement with those listed in Figure Two for the local precipitation,

However, the values reported for Hurricanes Fern and Chloe are clearly too great to be accounted for by dust wash-out. A possible explanation may be air-sea surface interaction. The somewhat similar distribution of pesticides, particularly p,p'-DDE, between slicks, Barbados wash water and hurricane rain water again indicates a possible causal relationship. Surface slicks may be formed by internal waves or by wind-induced Langmuir circulation when the wind force is Beaufort 3 or greater (Ewing, 1950). Both these mechanisms occur in tropical cyclones. Sutcliffe, Jr., Baylor and Menzel (1963) have shown that organics are concentrated and removed from sea water by adhering to droplets formed when bubbles burst at the surface, particularly the organic film in slicks. Blanchard (1964) has shown that droplets that rise from the sea in the surf zone carry a highly compressed surface active film. Both surf and bubble formation greatly increase in the ocean under the influence of cyclonic winds and surface area increases accordingly.

Gatz (1966) has determined that contaminants deposited in rain from most convective storms are drawn into the storms from low levels of the atmosphere, along with water vapor. Ostlund (1967) has determined that the input of sea water to a hurricane is two to three times that of water vapor already present by tritium measurements. Ostlund found that the amount of sea water vapor present increases steadily to the eye of the hurricane. A similar situation occurred with the pesticides in Chloe. Fern was a minimal hurricane while Chloe was fully developed. The fact that Chloe had more pesticide load than Fern can be accounted for by the increased sea state in Chloe and the consequent increase in bubble and spray formation.

The removal of only 20 kg of pesticide from the ocean by a storm covering $(5 \times 10^5 \text{ m})^2$ to an altitude of $8 \times 10^4 \text{ m}$ would result in $20 \times 10^{-12} \text{ g/L}$ if uniformly distributed and 50% washed out.

The extent of slicks in the open ocean is not known but their occurrence has been noted throughout the seas of the world (Ewing, 1950) and are believed to exist throughout all oceans (Williams, 1967). If one assumes that slicks cover only 1/10 as much area in the open ocean as in coastal areas the value would be about 1%. Further, let it be assumed that the true oceanic concentration of pesticides in slicks is only 1/10 of that found for Caribbean waters. Finally,

if it is assumed that only 50% of this pesticide is removed from the sea surface during droplet formation by surf and bursting bubbles and advected into a cyclone's convective circulation, slightly more than 20 g of pesticide-would still be provided.

Thus, it seems quite possible that somewhat the same mechanisms which result in the distribution of sea water in tropical cyclones also account for the distribution and increased amounts of organochlorine pesticides present in these storms.

However, it should be noted that nothing is known about the role the atmosphere may play in the transport of pesticide vapors as research is just beginning in this field (Barney, II, 1969). Up to 1×10^{-7} g/m³ of DDT, toxaphene and parathion vapors in air has been found at Orlando, Florida (Stanly, 1968), an amount which exceed by 10^6 those reported here. It seems likely that this source of pesticides in the air may be important to the interpretation of the results noted.

Summary

Over twice the amount of chlorinated pesticides originally reported for Barbados (78×10^{-15} g/m³) has been found (168×10^{-15} g/m³). The additional pesticides are recovered from the water used to wash the dust from the nets. The distribution of pesticides in this wash water fraction, particularly p,p'-DDE, is similar to that found in sea water slicks. Slicks may concentrate pesticides in sea water up to at least 10^5 and reflect concentration gradients even though the amount of pesticide in the water is undetectable. The amount of pesticide in solution in highly contaminated estuaries is extremely low, often below the part per trillion level. However, surface slicks from such estuaries have been found to have over 1-2 parts per billion. Because there is a high biological activity associated with slicks, this pesticide concentration may have important ecological implications. The occurrence of organochlorine pesticides in tropical rainwater and cyclones, including that collected by aircraft far from land, is reported. The somewhat similar distribution of pesticides in cyclones, wash water and slicks, particularly p,p'-DDE, may indicate a causal relationship. The high pesticide content in these cyclones cannot be accounted for by dust wash-out, as can the pesticide content in trade wind showers. The increase in pesticide content is probably accounted for by the removed of pesticides from the sea surface, where they are concentrated in slicks, during droplet formation by surf and bursting bubbles. The amount of pesticide vapors transported by air is virtually unknown but it seems likely that it may be of importance.

Index to pesticides

Aldrin	1,2,3,4,10,10-hexachloro-1,4,4a,5,8a-hexahydro-1,4-endo-exo-5,8-dimethanonaphthalene
Chlordane	1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene
DDT	A mixture of 1,1,1-trichloro-2,2-bis(<i>p</i> -chlorophenyl)ethane and 1,1,1-trichloro-2(<i>o</i> -chlorophenyl)-2-(<i>p</i> -chlorophenyl)ethane
DDE	A mixture of 1-(<i>o</i> -chlorophenyl)-1-(<i>p</i> -chlorophenyl)-2,2-dichloroethylene and 2,2-bis-(<i>p</i> -chlorophenyl)-1,1-dichloroethylene
Dieldrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-exo-5,8-dimethanonaphthalene
Heptachlor epoxide	1,4,5,6,7,8,8a-heptachloro-2,3-epoxy-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene
Lindane-	gamma isomer of 1, 2, 3, 4, 5,6-hexachlorocyclohexane
Parathion-	<i>o,o</i> -diethyl <i>o-p</i> -nitrophenyl thiophosphate
Toxaphene-	chlorinated camphene containing 67-69% chlorine

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